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NOTES

ON

THE CHEMICAL GEOLOGY

OF

THE GOLD-FIELDS OF CALIFORNIA.

BY

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DURING three separate visits to the Pacific coast of North America I have had numerous opportunities of studying the geology of the Californian gold-fields, and of investigating the circumstances attending the chemical and physical changes which have formerly occurred and which, to a certain extent, are still taking place in those regions. Whilst carrying out these researches, various facts have come under my notice which appear to throw light on the formation of auriferous veins, as well as on the distribution of the precious metal in the rocks in which it is found.

I have endeavoured to embody in the following paper some of the results of my inquiries, in the hope that, should the conclusions to which I have arrived be shown to be fallacious, the facts which have been collected may nevertheless assist other investigators in arriving at a correct interpretation of the phenomena attending the formation of auriferous veins. In doing this, I propose to first give a short description of the gold regions, and subsequently to treat of their quartz veins, alluvial deposits, hot springs, and salt lakes, all of which are intimately connected with the chemical geology of the districts in which they occur.

Rocks of the Gold-Region of California.

The great sedimentary metalliferous belt of California lies on the western slope of the Sierra Nevada, beginning in the neigh-

* The substance of a paper read before the Royal Society, March 12th, 1868.

bourhood of the Téjon Pass, and extending through the State to its northern limit. In consequence, however, of various local circumstances, different portions of this band are of very unequal importance as gold-producing districts.

The principal auriferous region may be said to occupy the western portions of the several counties of Mariposa, Tuolumne, Calaveras, Amador, El Dorado, Placer, Nevada, Sierra, and Plumas, with portions of the eastern sides of Yuba and Butte counties.

The apparently limited extent of the auriferous belt towards the north, in the counties of Plumas and Butte, is, according to the State Geological Survey, not owing to the thinning out of the gold-bearing formation in these localities, so much as to its being here, as well as in Shasta and Siskiyou counties, in a great measure covered by large masses of lava of very recent origin. This has been poured fourth from Lassen's Butte and other volcanic cones in its vicinity; and, overflowing the older slates, it has covered them to a great depth with a non-metalliferous and almost indestructible capping.

Beyond Mariposa, in the southern portion of the gold-region, the slates are narrower and subject to interruption, and, from being more frequently and more extensively encroached on by the granite, they almost cease to form a continuous belt. This gradual decrease in the width of the auriferous formation from north to south, and the continuously increasing amount of metamorphism displayed, are very marked, since the granite progressively occupies a relatively larger portion of the Sierra, and by degrees descends lower down its flank.

The slates of the auriferous belt of California have been satisfactorily shown by Professor Whitney* to belong, for a great extent, to the Jurassic period, although the occurrence of numerous Triassic fossils in the gold-bearing rocks of Plumas county and elsewhere renders it more than probable that no inconsiderable portion of the slates in the heart of the gold-region are of that age. The sedimentary rocks of the great auriferous belt lying on the western slope of the Sierra Nevada principally consist of various slates and schists, sometimes containing nodules of white felspar, which is generally more or less decomposed. Among them are also found sandstones of various degrees of fineness (often transformed into quartzites), black talcose schists, with slates exhibiting a well-defined cleavage and silky structure, together with bands of crystalline limestone.

The rock constituting the principal mass of the Sierra Nevada, is a granite containing only a small proportion of quartz, and in which oligoclase is very abundant. In addition to quartz, fel-

* Geological Survey of California.

spar, and mica, the latter of which is well crystallized and often of a brilliant black colour, this rock incloses titaniferous iron, and occasionally crystals of sphene of a light yellow colour. Magnetic oxide of iron is also present in notable quantities, and consequently imparts this property to the enclosing granite. The granite of the Sierra appears to retain its peculiar characteristics throughout a great portion of its extent; but towards the southern extremity of the chain hornblende begins to make its appearance as one of the constituents of the rock; the mica at the same time becoming less plentiful, and losing its brilliancy and dark colour.

Lying between the band of metamorphic slates and the great central granitic mass forming the more elevated portions of the chain, are found various eruptive rocks, such as syenites, diorites, and porphyries. The first of these pass into granites by almost imperceptible gradations, and appear to belong to the same geological period. The diorites, on the contrary, are of more recent origin, and contain neither sphene nor titaniferous iron, although they enclose a considerable amount of magnetic oxide of iron. In many places diorite is observed to traverse the granite in the form of distinct dykes. The porphyries are comparatively of small extent, and contain crystals showing the usual striæ, indicating the presence of plagioclastic felspars.

Quartz Veins.

All the crystalline rocks in the vicinity of the sedimentary deposits contain numerous veins of quartz, which traverse the granite and diorites near their point of junction with the slates, and, in addition to gold, enclose crystals of iron pyrites and other metallic sulphides.

These quartz veins of the crystalline rocks are comprised within a narrow zone running from south to north, along the western flank of the mountains above the great band of metamorphic slates forming the most productive portion of the gold-region, and extend, in the vicinity of the line of junction, nearly throughout its whole extent.

The quartz veins of the band of metamorphosed slates occupying the western slope of the Sierra, and lower on its flank than the crystalline rocks above described, are numerous and important. They are not, however, by any means equally distributed throughout the region of slates, but are chiefly concentrated in a belt having a width from east to west of some twelve or fifteen miles, and extending from south to north throughout the whole length of the formation. These veins, for the most part, follow the general direction of the strata in which they are enclosed. This parallelism, however, is not

absolute, since in many instances a vein, besides having a somewhat different direction from that of the bedding of the enclosing rock, throws off branches cutting the slate at considerable angles.

One of the most remarkable gold veins in California is that extending from Mount Ophir, in Mariposa county, to Mokelumne Hill in Calaveras, a distance of over seventy miles. This lead*, which frequently crops boldly out above the surface of the ground, and varies in thickness from six to sixty feet, may in some places be traced for many miles across the country, and often presents an outcrop like an immense white wall. Although by no means continuous, this may be considered as an axis with regard to the other veins of the region, which have generally an almost similar direction, and are most frequently grouped at no very considerable distances from it.

The gangue of the auriferous veins of California is invariably quartz, which is either crystalline in its structure, or partially vitreous and semitransparent. In the majority of cases the quartz constituting an auriferous veinstone is ribboned in such a way as to have the appearance of a succession of layers parallel with the walls of the lead; and some one or more of these laminæ are not unfrequently far more productive of gold than the others.

In some instances these parallel bands are separated from each other by a thin layer of quartz, slightly differing, either in colour or structure, from that forming the seams themselves; or they may be only distinguished by a difference of the colour or structure of two adjoining members of the series.

In many cases, however, laminæ of the enclosing slates divide the vein into distinct bands; and in such instances it will be observed that the thickness of the interposed fragments of slate is sometimes not greater than that of a sheet of the thinnest paper. Cavities or druses containing crystals of quartz sometimes occur in all the auriferous veins of the country; and a certain amount of crystallization may also not unfrequently be remarked along the lines of junction of the several bands of which a vein is composed. In such cases crystallization appears to have been set up on the surface of the last-deposited stratum, which has induced the formation of a similar crop of crystals on the layer subsequently formed on its surface. Quartz crystals, however, rarely occur in notable quantities in any of the most productive veins; and when the structure of a lead is highly crystalline, and the quartz more than ordinarily transparent, it is con-

* In California a quartz vein is called a "lead," and in Australia a "reef." In the gold-regions of the latter country the term *lead* is applied to the deposits of the "deep placers."

sidered an unfavourable indication with regard to its auriferous character.

The quartz considered by miners as most "favourable for gold" is seamy, stained by oxide of iron arising from the decomposition of pyrites, mottled, and somewhat marble-like in appearance. In addition to ordinary quartz in a more or less crystalline form, amorphous hydrated silica, or semi-opal, and chalcedony are occasionally met with : and in some instances the opal is interfoliated with layers of true quartz, and is sufficiently auriferous to repay the expenses of treatment.

Generally the walls of auriferous veins are smooth and well defined, often affording evidence of a considerable amount of dynamic action; and in the case of the lead being divided into bands by interfoliations of slate, these, to a less extent, are sometimes marked by groovings indicative of mechanical motion. Between the vein and the enclosing rock there is sometimes, but not always, a thin stratum of clay, which occasionally encloses small particles of gold.

The metallic minerals enclosed in the gangue of auriferous veins are ordinary iron pyrites, blende, and galena, and, less frequently, arsenical pyrites, magnetic and copper pyrites, and cinnabar. These sulphides invariably contain gold; and veins in which some one or more of them does not occur in considerable amounts, are not regularly and lastingly productive. In the earlier days of quartz-mining these sulphides were allowed to escape, and "free gold" was alone obtained; but at the present time they are all carefully collected, and form an important addition to the profits of the miner.

Near the surface iron pyrites and other sulphides become decomposed by the action of air and the percolation of meteoric water through the mass, staining the quartz of a red or brown colour, and leaving the gold in a form highly favourable for amalgamation. Under such circumstances numerous cubical moulds of iron pyrites are found in the veinstone; and although this mineral has been entirely removed by chemical action, the cavities remaining contain finely divided gold, obviously liberated by the decomposition of pyrites.

Beneath the line of natural drainage of the country the sulphides remain undecomposed, and the extraction of gold becomes more difficult; but if "rock" containing crystals of pyrites, be placed in nitric acid and allowed to remain for a few hours in a warm place, the sulphide becomes dissolved and finely divides, or filiform gold will often partially occupy the resulting cavities.

In addition to the gold thus enclosed in metallic sulphides, grains and small plates of that metal are disseminated throughout the veinstone; and this is particularly the case in the vici-

nity of certain coloured streaks, generally nearly parallel with apparent lines of deposition of the quartz. When gold is found lining a cavity in a lode, or is enclosed in plastic clay, it is often in the form of crystals, which are usually either octahedrons or cubes modified by planes of the octahedron or rhombic dodecahedron. When crystallization takes place in a narrow fissure, the crystals are much flattened.

In one of the detrital beds in the vicinity of the village of Volcano, in the county of Amador, a distinctly marked quartz vein may be observed intersecting the gravel, and evidently formed by the action of water holding silica in solution. The mass of this lode consists of agate and chalcedony, portions of which are coloured by ferruginous stains. In speaking of this vein, Professor Whitney says, "This is not by any means an isolated case; other localities have been noticed where all the conditions necessary to the formation of quartz veins, similar in their general features to those in the auriferous slates, must have existed during the most recent geological epoch."

With reference to this subject, Dr. Oxland* writes me as follows:—"The recent quartz vein containing argentiferous pyrites, of which I spoke to you when we met in California, is situated at Sulphur Springs, Bear Valley, about ten miles north-east of Borax Lake. This locality is resorted to by invalids for the purpose of bathing in the hot waters, which are supposed to possess medicinal properties, and which flow in very considerable quantities out of the foot of a hill on the north side of the creek.

"This water, which contains carbonate of soda, chloride of sodium, and a little borax, is perfectly bright and clear, but so hot, that it has to be conducted into a large reservoir to cool before it can be admitted into the tubs provided in the wooden bathing-sheds.

"The hill out of which this hot water flows rises about 400 feet above the cañon through which the waters make their escape, and near its summit a deposit of sulphur has been opened upon. This has been covered to a depth of several feet by vegetable mould, and Manzanita bushes are now growing luxuriantly upon it. In cutting a roadway from the valley to the sulphur deposit, a vein of friable quartz, evidently due to the action which has produced the solfatara, was cut through. This silica is banded in the direction of the vein, and contains finely divided iron pyrites. I took what I considered a fair sample of this quartz, which afforded me 16 ounces of silver per ton. Many of the nuggets of gold obtained in the immediate neighbourhood have been found with large pieces of cinnabar adhering to them."

* Formerly of the Toland Medical College, San Francisco, but now of Plymouth.

Some attention has also been recently directed to bands of auriferous slate found in the copper-bearing band west of the main gold-belt of the State, and in the foot hills of the Sierra. Of the deposits of this description, those near Lincoln, in Placer county, and at Quail Hill, in Calaveras, are the most remarkable.

In these localities the gold, instead of being obtained from well-defined veins chiefly composed of ordinary quartz, is enclosed in bands of siliceous slaty rock, extending north-west and south-east, and dipping in conformity with the other strata of the district. At the surface the Lincoln deposit is chiefly distinguished from the other slates of the neighbourhood by being, in places, deeply stained by oxide of iron, and forms a low out crop of about 3000 feet in length and 200 feet in width.

Where this has been cut into, it has been found to consist of alternating bands of clay-slate stained by oxide of iron, and of a friable sandy quartz still retaining distinct evidences of stratification, and which under the microscope presents the appearance of a siliceous skeleton from which the more soluble constituents have been removed by aqueous agencies.

Through these bands, and running parallel with their stratification, dykes of felspathic rock make their appearance, and contain small opaque white crystals too much decomposed to admit of identification. These, like the slate itself, contain gold, but, in the case of the felspathic rock, in very small quantities only. In the slate are also found lenticular masses of blende and iron pyrites, both auriferous, with stains of carbonate of copper. The whole mass of the stratified rock contains a certain amount of "free gold," although the seams vary considerably in their yield, some of them affording mere traces, whilst others assay as much as 3 oz. per ton. The whole of the gold in the portions of the deposits as yet worked is in a "free" state; but it is probable that below the water-level it may be found associated with various sulphides, by the decomposition of which in the upper portions the precious metal has become liberated. The pyrites and blende, in addition to gold, afford by assay a small quantity of silver; and particles both of native silver and native copper may be extracted by washing the decomposed slates.

As a general rule, the quartz lodes of California have not been found to be more subject to impoverishment in depth than other mineral veins, some of them having been worked on their dip for a distance of above 1200 feet without any diminution of their yield having taken place.

In order to determine the chemical and physical composition of quartz forming the gangues of some of the principal auri-

ferous veins of California, I have made analyses of the veinstones from several of the most productive mines, and have examined under the microscope thin sections from a great number of others. My experiments have, however, been chiefly confined to various lodes in the vicinity of Grass Valley, in the county of Nevada, with which I have had numerous opportunities of making myself acquainted, and among which are comprised some of the most productive veins of the country.

In preparing thin sections for examination I have carefully avoided the use of any kind of polishing-powder; and the arrangement made use of for examining them has generally been a $\frac{1}{4}$ objective, by Ross, with draw-tube and eyepiece magnifying about 400 linear. In some cases, however, a magnifying-power of above 1000 linear was employed.

Examination of Quartz from the Kate-Hayes Vein.—Fragments of quartz taken from near the surface of the Kate-Hayes vein, Grass Valley, and having a specific gravity of 2·59, gave the following results.—

Water lost at 212° F.	0·26	
Water lost by subsequent ignition .	0·70	
Silica	93·32	
Alumina	2·03	
Iron	1·29	Iron pyrites.
Sulphur	1·45	Iron pyrites.
Potash	0·40	
Soda	0·21	
Lime and magnesia	traces	
	99·66	

This vein is composed of parallel bands, some of which contain small quantities of chlorite and iron pyrites. The quartz of which it consists is of a greyish colour, not very distinctly crystallized, has a peculiar greasy appearance, and contains cavities, on the surfaces of which have been deposited guttate silica of a chalcedonious description. This rock contains gold in the form of large scales and plates.

When examined under the microscope with a low power, this quartz presents in some places a cloudy appearance, and is found to contain a few small cubical crystals of iron pyrites, together with cavities filled by chalcedonious matter. Under a higher power it is seen to contain fluid-cavities of about one-thousandth of an inch in diameter, and in which the ratio of the vacuity to the cubical content of the cavity is about 1 : 10.

This veinstone also encloses small cavities which appear to be lined with clay, and in which no vacuities can be seen. It likewise contains gas-cavities and *markings* very similar in appearance to the "glass-cavities" described by Mr. Sorby as occurring

in porphyritic pitchstone, in the leucite of the lava of Vesuvius, and in the augite of some trappean rocks. In the case of quartz from the auriferous veins of California, I am, however, inclined to believe that they are due to crystallization only, since I have never been enabled to discover globular vacuities in any of them, and precisely similar markings may be observed on many quartz crystals on examining their surfaces by the aid of an ordinary lens. Should a fresh deposit of silica immediately take place on the planes of a crystal thus marked, an appearance not unlike glass-cavities would be the result; and if the depressions on the original crystal should become coated with clay, by deposition from turbid water, before the formation of the succeeding stratum of quartz, a certain degree of opacity, like that observed in the quartz of many auriferous veinstones, would be caused. It is also obvious that crystallizations of other minerals might take place in such depressions; and these, becoming covered by the succeeding deposit of quartz, would have, to a great extent, the appearance of having been formed from a slag or glass in the act of cooling from a state of fusion.

That crystalline quartz is frequently produced by successive depositions we have abundant evidence from specimens in which a crystal is seen to enclose others, each successively smaller than that which immediately surrounds it. Clay and oxide of iron are also in this way deposited on the surfaces of crystals during the interval which elapses between the formation of two distinct layers, as may be observed at the tin mines of Schlackenwald and in other localities, where crystals are obtained of which the various layers are so separated from each other by a clayey deposit as to admit of being readily divided into a series of cup-like envelopes, finally enclosing a central nucleus.

Examination of Quartz taken from the Norambagua Mine.—Specimens of quartz taken from a depth of 500 feet at the Norambagua mine, situated about four miles south of Grass Valley, and having a specific gravity of 2·60, were selected for analysis and afforded the following results:—

Water lost at 212° F.	0·19
Water lost by subsequent ignition	0·39
Silica	96·29
Alumina	1·42
Iron	0·55
Sulphur	0·57
Arsenic	traces
Potash	0·36
Soda	traces
Lime and magnesia	traces
	99·77

The Norambagua vein is enclosed in a crystalline rock locally known as syenite; but in some parts of the hill its composition would rather entitle it to be classed as a diorite. This vein, which is seldom more than a foot in thickness, is divided by headings into thin laminæ parallel with its walls, and is chiefly composed of greasy-looking quartz, showing rather faint indications of crystallization. Between the several laminæ of silica there are not unfrequently thin seams of blue slate, which have evidently been subjected to considerable pressure, and which cause the veinstone to be easily separated into parallel bands. In some places iron pyrites and arsenical pyrites are abundant; but in selecting specimens for analysis those portions of the veinstone containing a visible amount of sulphides &c. were avoided.

A microscopical examination of sections cut from this vein showed that it contains fluid-cavities of about $\frac{1}{5000}$ of an inch in diameter, in which distinct vacuities could be observed. It also encloses a few gas-cavities, and some apparently containing clay, together with markings like those observed in the quartz from the Kate Hayes.

Examination of Quartz from the North-Star Mine.—Some of the ordinary white quartz from the North-Star mine, near Grass Valley, having a specific gravity of 2·61, was next subjected to analysis, and gave the following results:—

Water lost at 212° F.	0·07
Water lost by subsequent ignition	0·03
Silica	98·61
Alumina	0·82
Peroxide of iron	traces
Potash	0·24
Soda	traces
	99·77

This vein, which sometimes thins down to a mere seam, and at others has a width of 6 feet, is one of the most productive in the district, and has been worked to a depth, on the inclination of the lode, of 750 feet. All the specimens were taken from near the bottom of the workings.

The quartz, of which it is principally composed, is of a milky colour, and presents indistinct crystalline faces in whatever direction it may be broken. Like nearly all the auriferous veins of the country, it exhibits a tendency to an arrangement according to bands parallel to the walls of the enclosing fissure, and, wherever it is most productive, contains iron pyrites and other sulphides.

Thin sections of this veinstone, examined under a high power, show a few minute fluid-cavities, together with numerous small

cavities apparently containing clay, some larger ones in which the clay appears coloured by oxide of iron, and a great number of the markings before referred to, and which are believed to be due to crystallization.

The most remarkable circumstance in connexion with this vein is the occurrence within it of large quantities of hydrated silica of a bluish-grey colour: this has a resinous lustre, and possesses a distinct conchoidal fracture, but exhibits well-defined lines showing layers of deposition parallel with the other bands of which the lode is made up. It is found in the form of a series of lenticular deposits, often several fathoms in length, interlaminated with the ordinary crystalline quartz, from which it is separated by a thin heading of unctuous clay. This substance, which has the appearance of semi-opal, is frequently 6 or 8 inches in width in its thickest part, and gradually tapers off in all directions in such a way as to assume a lens-like form. This hydrated silica sometimes encloses iron pyrites, and contains a sufficient amount of the precious metal to render its treatment commercially advantageous.

Examination of Semi-opal from the North-Star Mine.—A specimen of this substance submitted to analysis had a specific gravity of 2·01, and afforded the following results:—

Water	8·08
Silica	86·69
Alumina	1·92
Protoxide of iron	0·99
Lime	1·44
Magnesia	0·23
Potash	0·26
Soda	0·05
	99·66

This substance, at a temperature of 212° F., lost water slowly during several days, and, placed under a bell-glass over fused chloride of calcium, continued to lose weight after 300 hours, when the loss amounted to 5·11 per cent. Under these circumstances no attempt was made to determine separately the water lost at 212° F.; but the amount of hygrometric moisture present must have been exceedingly small, as this specimen was taken at the same time and kept in the same cabinet with the crystallized variety, which lost only 0·07 per cent. of moisture at 212° F.

Examined by polarized light this mineral does not show any evidence of crystallization; but when a high power is employed, it appears full of small elliptical cavities in which no vacuities were observed.

Examination of undecomposed Auriferous Slate from Lincoln.—A specimen of the undecomposed auriferous slate from the

neighbourhood of Lincoln in Placer county, had a specific gravity of 2·55, and yielded the following results:—

Water lost at 212° F.	0·31
Water lost by subsequent ignition	1·88
Silica	72·05
Alumina	17·87
Peroxide of iron	1·98
Lime	1·65
Magnesia	0·38
Potash	1·71
Soda	2·40
	100·23

When examined under a low power, this slate is seen to be made up of angular fragments of quartz connected together by clayey matter, their largest planes being parallel to the lines of cleavage. It also contains numerous spots of peroxide of iron, which in many instances still retain the cubical form of iron pyrites. By the aid of a high power the quartz fragments are seen to enclose a few small gas-cavities; and one or two fluid-cavities, with distinctly visible vacuities, were observed.

Examination of decomposed Auriferous Slate from Lincoln.— The decomposed siliceous matter before referred to, somewhat resembling chalk in appearance, was found to have a specific gravity of 2·50, and on being analyzed gave the following results:—

Water lost at 212° F.	0·11
Water lost by subsequent ignition	traces
Silica	93·33
Alumina	4·46
Peroxide of iron	traces
Lime	0·75
Magnesia	0·43
Potash	0·52
Soda	traces
	99·60

When examined under the microscope, this substance appears to consist of the siliceous skeleton of the auriferous slate from which the aluminous and ferruginous matters have been almost entirely removed. The angular fragments of quartz, being thus deprived of the cementing material which originally bound them together and gave solidity to the mass, remain in a disintegrated and friable state, although still retaining distinct indications of stratification.

The number of well-defined fluid-cavities in the veinstones of the auriferous lodes of California is exceedingly limited; and in

order to obtain sections affording good examples, even of small size, it is necessary to select such bands as may be more than ordinarily crystalline, or to operate on thin fragments of crystals sometimes found lining the interior of drusy cavities.

In the more opaque and generally most auriferous portions of veins, the cavities are numerous but exceedingly small, and are often so opaque (apparently rendered so by being internally coated by a lining of clay) that no vacuities can be distinguished. Some of the bubbles, contained in cavities requiring an arrangement magnifying a thousand linear to be distinctly seen, were observed to move freely about.

Out of more than sixty sections of veinstone examined, only some six or eight were found to contain fluid-cavities of sufficient size to admit of any attempt at accurate measurement; but in all cases there appeared to be considerable differences in the relative dimensions of the vacuities and the enclosing cavities, and I consequently ascertained by direct experiment the temperatures at which they severally became filled. For this purpose a small bath, made of sheet brass with a piece of microscopic glass fitted into each side, was employed. The section to be examined was clipped on the inside of one of the small panes of thin glass, and the bath filled with spermaceti into which the bulb of a thermometer was inserted. By attaching this apparatus to the stand of a microscope, of which the body was fixed horizontally, heating the bath, and throwing the light of an oil-lamp on the object by means of a condenser, it was easy to study the appearance of the different cavities under various conditions of temperature.

The magnifying-power employed was in this case about 275 linear, and consequently only such sections as contained tolerably large cavities could be satisfactorily examined. In every instance, however, they were found to require very different degrees of temperature to become full, since in the same specimens some of the vacuities disappeared at 180° F., others filled at temperatures slightly above that of boiling water, whilst many, though much reduced in size, remained perfectly visible at 365° F.*

Alluvial Deposits.

Although a very large amount of the gold annually obtained was no doubt originally derived from auriferous veins, not more than about one-third of the precious metal now collected is procured directly from that source. The larger proportion of the gold brought into the market is derived from alluvial diggings,

* As an illustration of this fact, the results obtained by heating the section of a crystal of quartz from the great Mariposa vein may be given. Six several vacuities disappeared at the following temperatures, 250°, 260°, 280°, 290°, 310°, and 320° F. Others were not nearly full at 362° F.

in which it is associated with clay, sand, and gravel, from which it is separated by washing.

These gold-bearing drifts belong to at least two geological epochs, both comparatively modern, although the later period is distinctly separated from the earlier, its materials being chiefly derived from the disintegration and redistribution of the older deposits.

In California the more ancient deposits, or *deep placers*, are probably referable to a river-system different from that which now exists, flowing at a higher level or over a then less elevated country, and frequently nearly at right angles to the direction of the main valleys of the present period.

The sources from which the supply of gold is derived are therefore the following:—

(1) Auriferous veins, most frequently enclosed in metamorphic slates.

(2) The distribution of gold by ancient river-systems, giving rise to *deep diggings*.

(3) The redistribution of placer gold by the present river-system, forming accumulations known as *shallow diggings*.

The deep placers are in many localities covered by a thick capping of lava; and in some places the eruptive matters covering the auriferous deposits occur in the form of basaltic columns, beneath which are found the layers of sand, gravel, and boulders with which gold is associated. The wood which occurs in these gravel-beds is either beautifully silicified, or is replaced by iron pyrites. In such localities it not unfrequently happens that a piece of wood will be observed of which one end had been converted into lignite, whilst the other remained unaltered; but the whole having subsequently become silicified, now presents the appearance of a combination of alabaster and jet, each portion still retaining the structure of the original wood.

In the more clayey strata of these sedimentary deposits, leaf-beds and impressions of leaves are not unfrequently found; and an examination of these made by Dr. Newberry authorizes the conclusion that the auriferous deposits lying beneath the lava are of tertiary age, and that in all probability they generally belong to the later Pliocene epoch*.

In many localities, and particularly between the south and middle forks of the Yuba River, these auriferous gravels have frequently, where exposed to denudation, a thickness of 120 feet, and of more than 250 feet where they have been protected by a volcanic capping. These vast auriferous beds are composed of rounded masses of all the eruptive and metamorphic rocks which occur above them in the Sierra. As a general rule, the lower

* Geological Survey of California, pp. 250 & 251.

portions consist of larger boulders than the upper; but this does not exclude the occasional appearance of large rounded masses of rock among the middle or upper members of the series.

Water-worn gold is, to a greater or less extent, disseminated throughout the whole mass of these deposits; not, however, with uniformity, but always with greater abundance near the bottom, and more particularly in direct contact with the *bed-rock,* which is invariably grooved and worn by the action of water. The materials of which these deep placers are composed are frequently consolidated into a sort of hard concrete by being firmly bound together by crystalline iron pyrites; and sometimes this cementing materially partially consists of carbonate of lime and amorphous silica. In many cases, as at some places in the county of Nevada, the sand, gravel, and boulders are firmly held together by a material consisting almost entirely of silica, in such instances giving rise to an exceedingly hard conglomerate.

When in the deep placers this consolidation of the materials of which they are composed has taken place, it is known by the name of *cement,* and often necessitates the employment of large quantities of gunpowder for its removal.

The silica forming one of the ingredients of the auriferous conglomerates is rarely met with in a crystalline form; but near Kenebeck Hill I found a cavity, resulting from the junction of several pebbles, completely lined with well-defined crystals of quartz. One of these, on being sufficiently reduced in thickness by grinding, did not show under the microscope the usual fluid-cavities of the quartz of the ordinary veins of the country. In some localities the silicified wood is found in the form of large trees, of which the entire mass has become replaced by a siliceous deposit; whilst in others this transformation has taken place to a limited extent only, and on breaking up a large trunk the central portion still retains the structure and properties of the original wood.

Where the cementing material of the conglomerate chiefly consists of pyrites, the enclosed trunks of trees are usually replaced by that mineral, although, of two pieces of wood lying in close proximity to each other, one may have become silicified, whilst the other is replaced by iron pyrites. On examining under the microscope the leaves which often form thin beds in the sands and clays of the tertiary auriferous river-beds of the gold-regions, they are seen to be covered by small guttate deposits of semitranslucent silica; and on burning some leaves found in these drifts in the county of Nevada, I found that, after long digestion in hydrochloric acid, they afforded 25·21 per cent. of a siliceous ash.

A specimen of silicified wood (coniferous) from French Corral

lost in the water-bath 0·59 per cent. of moisture; and by subsequent ignition the further loss amounted to 8·46 per cent., thus making the total loss 9·05 per cent. Another piece of wood from the same locality lost 0·56 per cent. at 212°, and 8·43 per cent. by subsequent ignition; in this case, therefore, the total amount of water contained was 8·99 per cent.

The assay of several specimens of the cementing pyrites showed that it invariably contained a small but very variable amount of gold. In order to ascertain whether this exists in the form of water-worn grains mechanically enclosed within the sulphides, or in the form of spongy and filamentary particles similar to those met with in the pyrites of auriferous veins, I dissolved various samples in nitric acid, and afterwards subjected the residues to microscopical examination. In this way I detected granules of the precious metal which had evidently been worn by the action of water, whilst others appeared not to have been subjected to such attrition. However, on examining pyrites forming the substance of various fossilized trees, I was unable, when the samples were taken from the inside of the trunks in order to avoid the possibility of accidentally attached particles, to detect an appreciable amount of gold, even when the assays were made on several hundred grains of the material; but my experiments were conducted on specimens from one locality only (French Corral), and in Australia very different results appear to have been obtained. Mr. Ulrich states that "in the gold-drifts pyrites is often found incrusting or entirely replacing roots and driftwood; such specimens very quickly decompose on exposure to the atmosphere, and samples have, on assay by Messrs. Daintree, Latta, and Newberry, yielded from a few pennyweights to several ounces of gold per ton." According to Mr. H. A. Thompson, "a beautiful specimen of crystallized iron pyrites, deposited on a piece of wood taken from the drift immediately below the basalt at Ballarat, gave, by assay, 40 oz. of gold per ton; and in another case, where only the pyrites from the centre of an old tree-trunk was examined, the yield was over 30 dwt. of gold per ton. Some of the fine dust obtained in washing out the gold at the Royal Saxon claim, Ballarat, yielded, by assay, over 15 oz. of gold per ton. When placed under the microscope, this dust was seen to be composed of minute crystals of pyrites aggregated into round pellets from $\frac{1}{300}$ to $\frac{1}{100}$ of an inch in diameter, the surfaces being roughened by the projecting angles of the crystals, and unwater-worn" *.

* Notes on the Physical Geography, Geology, and Mineralogy of Victoria. By Alfred R. C. Selwyn and George H. F. Ulrich. Pp. 36. (Melbourne, 1866.)

Hot Springs.

Hot and boiling springs are exceedingly numerous throughout California; and considerable accumulations of sulphur, together with evidences of extensive solfatara action, are met with in different sections of the State. To attempt even a mere enumeration of all the various localities where these phenomena have been observed would occupy more space than it is my intention to devote to the subject; and I shall therefore confine myself to a description of two or three of the more remarkable examples, selecting such only as appear to have the most direct bearing on some of the chemical and geological changes which have been produced, and are, to a certain extent, still going on in this portion of the American continent.

Borax Lake.—Lying about a mile beyond the ridge which borders Borax Lake on the north-east is a locality in which solfatara action is still exceedingly active, and where a large amount of sulphur has accumulated. This is called the "Sulphur Bank," and is of some six or seven acres in extent. It consists of a much decomposed volcanic rock traversed by innumerable fissures, from which steam and gas are constantly issuing, and over and through which large quantities of sulphur have been deposited in such a way that, at a little distance, the whole mass appears to consist of this substance. Into some of the cavities a pole may be inserted for several feet; and they are often lined with stalactites and beautiful crystallizations of sulphur.

This sulphur is being constantly deposited, and its deposition is attended by the evolution of aqueous vapour, carbonic and boracic acids; but this apparently takes place without the emission of sulphuretted hydrogen. The gaseous matters issuing from the crevices have usually a temperature of about 95° F., and appear to be the agency by which various mineral substances now deposited in the cavities were brought to the surface. Sulphur is deposited on the sides of the various fissures, either in groups of crystals, as stalactites, or in translucent amorphous masses of a beautiful yellow colour. It is sometimes intermixed with cinnabar, but more frequently with minute crystals of iron pyrites, and with pulverulent silica, blackened by the presence of a hydrocarbon having the appearance of coal-tar. With these, according to Dr. Oxland, are found silver and traces of gold*.

On the sides of the cavities gelatinous silica is found coating chalcedony and opalescent silica in various stages of formation,

* Mining and Metallurgy of Gold and Silver, by J. Arthur Phillips, p. 11. E. and F. N. Spon: London.

from the gelatinous state to that of the hardest opal. This indurated silica is sometimes colourless, but is more frequently permeated by cinnabar and iron pyrites, or blackened by the tarry matter before referred to. Cinnabar is also found in striæ, and occasionally even in veins and concretionary masses of considerable thickness; where the bituminous matter occurs in the largest quantity, and the mass consequently becomes black and friable, cinnabar is replaced by globules of metallic mercury.

On the edge of Clear Lake near the sulphur bank is a hot spring, of which the outlet, even when the water is low, is partially beneath the lake, so that the amount which flows from it cannot be ascertained. Hot water, however, rises through the sand at various points, extending over a considerable area; and Mr. Moore, of San Francisco, who analyzed the water from this locality, has found that, in addition to chloride of sodium and carbonate of soda, it contains a large quantity of borax, and above a hundred grains of ammoniacal salts per gallon. Lying immediately at the foot of the sulphur bank are several springs of cold water, some of which contain carbonate and sulphate of soda, whilst others yield boracic acid. All these springs evolve large quantities of carbonic acid.

The chalcedony and semi-opal from this place, when examined under the microscope, are seen to enclose cubical pyrites, together with crystalline cinnabar; but the latter mineral appears to have been generally deposited in an amorphous state. Specimens of chalcedony taken from the fissures in the sulphur bank were, when first broken, so extremely soft as to readily receive an impression of the nail; but on reaching England they had become hardened, and had assumed the ordinary characteristics of that mineral.

Thin sections of these specimens showed a structure like that of fortification-agate, and were traversed by numerous fissures parallel to lines of incipient crystallization, besides which they were in places stained by oxide of iron.

Boiling Springs.—About fifteen miles east of Little Lake, situated in lat. 35° 50′ north and long. 18° 10′ west from Greenwich, 200 miles north of Los Angeles, are numerous boiling springs. The first group covers several acres of the southern declivity of a granitic hill, and is no longer in a state of great activity, although numerous apertures are giving off an abundance of steam and acid vapours, and small quantities of sulphur are being deposited around the various openings. In the immediate neighbourhood of these springs the granite has been reduced to the state of a soft hot mud very dangerous to walk over; and a large area having become reduced to this pasty condition, it has flowed down the side of the elevation and become deposited

in layers on the low ground near its base. It was also observed in one of the ravines that mud resulting from the upper springs had sometimes flowed over and choked those lower in the series; and this appears to have given rise to the formation of fresh openings, and the progressive movement of the area of greatest activity up the side of the declivity.

About a mile to the west of these springs a high granitic mountain is traversed by an immense dyke of obsidian, which, having broken through it, has flowed for a considerable distance into the valley.

At the eastern foot of the hill on which is situated the first group of springs are numerous others in a much more active state. Here the ground is covered over a large extent by innumerable cones of plastic mud, varying from a few inches to three feet in height; these rise above the surface of a barren steaming swamp, and give issue to jets of watery vapour and streams of boiling water. In some cases these springs, instead of issuing from small cones as above described, evolve large quantities of steam and gas under the surface of water contained in basin-shaped reservoirs produced by their agency in the decomposed granite in which they are situated. By these means are formed a multitude of seething caldrons, in which the rapid ebullition of water keeps the mud in a constant state of suspension; and this is either white or of a reddish colour, in accordance with the amount of ferruginous matters present. To the east, at a distance of some three or four miles, were seen high ranges of evidently basaltic hills, the whole district being totally uninhabited except by a few Indians, some of whom were met with collecting oxide of iron to be employed as paint.

The appliances at command in such localities are usually of a limited character; but I was enabled to ascertain by means of litmus-paper that the water of all the springs examined had an acid reaction; and having filled a pint bottle with water from one of the largest of the basins, it was brought to England for analysis.

This amount, although manifestly too small to allow of a very accurate analysis, was sufficient to admit of the estimation of all the principal constituents. The following are the respective quantities of the different bodies present, calculated on an imperial gallon of the filtered water :—

Contents per Imperial Gallon.

	grs.
Silica	7·00
Alumina	7·70
Oxide of iron	traces
Lime	1·96
Magnesia	1·41
Potash	0·85
Soda	1·26
Chlorine	2·25
Sulphuric acid	25·86

The foregoing results may be rendered thus:—

Contents per Imperial Gallon.

	grs.
Silica	7·00
Tersulphate of alumina	25·67
Sulphate of iron	trace
„ lime	4·76
„ potash	1·57
„ soda	2·87
„ magnesia	1·77
Chloride of magnesium	3·01
Free sulphuric acid	1·57
	48·22

It is somewhat remarkable that this water, issuing from the ground in a boiling state, should at the same time contain chlorides and free sulphuric acid; but it must be remembered that the acid is in an exceedingly dilute state, and that the water was collected immediately at the mouth of the aperture from which it emerged. It is probable that potash and soda may exist in the form of the bisulphates of those bases, since an excess of sulphuric acid is present.

It was observed that where these acid waters flowed away at a temperature of above 200° F. several low forms of vegetation (probably Confervaceæ) appeared to flourish, but to become less abundant and less vigorous where the temperature had become considerably reduced.

Steamboat Springs.—The most remarkable instance on the Pacific coast of the actual growth, on a large scale and at the present time, of mineral veins is probably that afforded by the boiling springs in Steamboat Valley, seven miles north-west to the Comstock silver vein and Virginia city.

These springs are situated at a height of about 5000 feet above

the level of the sea, at the foot of the eastern declivity of the Sierra Nevada. The rock in this locality presents several parallel fissures, either giving out heated water or simply ejecting steam. The first principal group of crevices comprises five longitudinal openings extending in a straight line for a distance of 3500 feet. Their general direction is north 6° west, and they are comprised within a band of about 600 feet in width. The fissures are separated from one another by intervals of from 40 to 60 feet, have each a thickness of about 12 inches, and are severally connected with each other by lesser openings, which intersect the first nearly at right angles.

These crevices are often full of boiling water, which sometimes overflows and escapes in the form of a rivulet, whilst at others it does not flow over, but violent ebullition is heard to be taking place at a short distance below the surface. The fissures are partially filled by a siliceous incrustation which is being constantly deposited on the sides, whilst a longitudinal central crevice allows of the escape of boiling water or steam. On the most eastern of these lines of fracture are several active centres of eruption, from which boiling water is often ejected to a height of from 8 to 10 feet. These waters are alkaline, and contain, in addition to carbonate of soda, the sulphate of that base, with chloride of sodium. There is also everywhere an escape of carbonic acid, whilst from some places sulphuretted hydrogen is also evolved. These products give rise to the deposition of sulphur, silica, and oxide of iron. The silica forms semicrystalline bands parallel with the walls of the fissures; and spongy deposits accumulate around some of the points of most active emergence in such a way as to form small circular basins, of which the edges go on continually increasing in height, so that each finally presents the appearance of a small volcano of boiling water.

At a considerable distance to the west of these, a second group having the same origin is observed; but this is no longer traversed by hot water, although it still gives off steam and carbonic acid at various points. This large dyke of quartz commences at its southern extremity by a number of fissures which subsequently converge into a single crevice, of which the two walls are of silica, and extend a distance of considerably over a mile. At its northern extremity a central fissure still remains open; but in other localities it is for the most part obstructed by siliceous concretions. Towards the south the siliceous deposits extended beyond the edges of the cleft, and have accumulated on the surface of the ground to a thickness of several feet, and for a distance of from 80 to 90 feet on each side of the fissure. These deposits almost entirely consist of more or less hydrated silica.

This silica presents itself in the form of a compact rock, much resembling in appearance the quartz of ordinary veins, with chalcedony, and occasional nodules of hyalite. This rock is, to a certain extent, metalliferous, and, in addition to oxide of iron, contains oxide of manganese, together with iron and copper pyrites. M. Laur states that he discovered metallic gold in this deposit, although I was myself unable to detect its presence.

These phenomena of the Steamboat Valley appear to indicate that metalliferous veins may be produced by mineral waters, in the fissures through which they circulate. On taking into consideration the principal circumstances connected with these veins, it will be observed that their eruptive activity is by no means equal throughout their longitudinal extent. This activity is concentrated around certain points, which appear to be the sources from which are principally discharged the waters holding various mineral substances in solution, and whence they subsequently become distributed throughout the fissures existing in the rock. It has been observed by M. Laur* that the slowness with which these incrustations are formed in the interior of the cavities, as compared with the great mass of mineral waters which escape over the edge of the various fissures, also shows that a large proportion of the metalliferous emanations may thus have been carried beyond them; so that, should they contain a non-oxidizable metal, such as gold, the superficial deposits may occupy a considerable surface and contain a great amount of wealth, although the vein from which it originally issued may be small and comparatively unimportant.

The rock enclosing the veins of Steamboat Springs is a granite, which in their vicinity is much decomposed, being often reduced to a cavernous skeleton of silica containing only a few scales of mica. The granite in this locality is poor in quartz, but rich in oligoclase, and contains magnetic oxide of iron, titaniferous iron, &c.

This rock, forming the bottom of Steamboat Valley, is overlain on its eastern and western flanks by a compact basalt containing magnetic oxide of iron together with various zeolitic minerals.

Examination of the siliceous deposit at Steamboat Springs.—A specimen of the siliceous deposit taken from the side of a fissure from which steam and carbonic acid were issuing in considerable quantities had a specific gravity of 1·99, slightly scratched felspar (orthoclase), and afforded by analysis the following results:—

* *Annales des Mines*, sixième série. tom. iii. p. 424.

Water lost at 212° F.	0·48
Water lost by subsequent ignition	6·16
Silica	92·64
Alumina	0·30
Potash	0·27
Lime, iron, and soda	traces
	99·85

This veinstone, which exhibited numerous parallel bands in the direction of the enclosing walls, was selected for analysis as having been most recently formed. On boiling 35·18 grains of this substance in a finely divided state during eight hours in 4 oz. of a strong solution of caustic potash, only 2·35 grains, or 6·68 per cent., of the silica present was dissolved.

A section of this substance examined under the microscope showed the reniform structure of chalcedony, together with patches of amorphous silica and small crystals of iron pyrites; but no other appearance of crystallization could be detected. This specimen contained a well-defined fluid-cavity, in which the vacuity occupied about one-tenth of its total volume. Another portion of the deposit, which, from being further removed from the sides of the fissure, must have been of older date, afforded only 4·72 per cent. of water, and distinctly showed the presence of crystalline silica. On carefully examining the great western vein before alluded to, considerable quantities of chalcedony were found; and in one of the cavities a few small perfectly defined crystals of quartz were discovered.

Alkaline Lakes.

In that portion of California lying on the east of the Sierra Nevada are Mono Lake and Owen's Lake, both considerable sheets of water highly impregnated with alkaline salts. Owen's Lake, at the southern extremity of which I was for some weeks encamped during the fall of 1865, lies in lat. 36° 20′ north, long. 118° west from Greenwich, is about twenty miles in length and eight in width. Owen's Valley is a narrow basin enclosed between high mountains, and has a length of about 140 miles, and an average width of 10 miles. On its western side it is bordered by the Sierra Nevada, which opposite the lake rises in peaks fourteen thousand feet in height. On the eastern side the mountains are more broken, although of nearly equal height, but nothing like a complete exploration of this region has yet been attempted; besides which it is so utterly barren and forbidding that the Indians, whose stronghold it still remains, are not likely for some time to be much interfered with by the indefatigable mining "prospecter." These mountains are bare,

and no stream of any importance flows from them into the valley, which is almost exclusively supplied by the melting of the snows which during the winter months accumulate in the upper portions of the Sierra.

This range, on the eastern side of the valley, is towards its southern extremity called the Inyo Mountains, whilst further north they are known as the White Mountains. Owen's River rises not far from the head of the San Joaquin, and near the southern extremity of the valley flows into Owen's Lake, which has no visible outlet, and whose banks are in many parts thickly coated by an alkaline incrustation. No fish inhabit its waters; but at certain seasons of the year it is resorted to by myriads of waterfowl attracted by the grub-like larvæ of a fly which deposits its eggs on the surface.

These grubs are about the length of a small grain of rice, but somewhat less in diameter, and are thrown on the lake shores by the waves in such vast quantities that they are collected by the Indians as an important article of food. In addition to these there are large quantities of minute crustacea closely resembling the *Artemia salina*.

Waters of Owen's Lake.—A sample of water taken January 3, 1866, from opposite Franklin's Ranch, had a specific gravity of 1·076, and on analysis afforded the following results:—

In an Imperial Gallon.

	grs.
Chloride of sodium . . .	2942·05
Sulphuric acid	589·12
Carbonic acid	1206·80
Silicic acid	55·34
Phosphoric acid	15·43
Potash	175·49
Soda	2127·07
Organic matter	16·94
	7128·24

The above results may be expressed as follows:—

In an Imperial Gallon.

	grs.
Chloride of sodium . . .	2942·05
Sulphate of soda	956·80
Carbonate of soda	2914·43
Sulphate of potash . . .	122·94
Phosphate of potash . . .	35·74
Silicate of potash	139·34
Organic matter	16·94
	7128·24

In addition to the substances above enumerated minute traces of iodine were found, but in such small proportions that its presence could only be detected when large quantities of water were operated on.

As the samples employed for analysis were, before being brought to this country, concentrated by boiling, it is probable that a loss of carbonic acid must have taken place should any alkaline sesquicarbonate have been originally present.

The incrustations, which at certain seasons of the year are found to the extent of hundreds of tons on the lake-shores, chiefly consist of carbonates of soda in which the proportion of sesquicarbonate is variable; and specimens were examined in which monocarbonate only was present. Besides the carbonates of soda, these deposits contain 3 per cent. of chloride of sodium and about 5 per cent. of sulphate of soda, together with a trace (0·22 per cent.) of silica.

Summary.

The following are some of the more important facts observed on a careful examination of the gold-regions:—

(1) The quartz veins of California almost uniformly exhibit evidences of having been formed by successive siliceous deposits parallel to the walls of the enclosing fissure; and when fragments of exfoliated slaty rock become enclosed, their planes are usually parallel to those of the quartz in which they are imbedded.

(2) All remuneratively productive gold veins contain notable quantities of iron pyrites and other metallic sulphides; and the association of these bodies is so constant and remarkable, that it is probably the result of some chemical action regulating the distribution of the precious metal.

(3) The auriferous quartz of the Pacific gold-fields invariably contains a certain quantity of potash together with a small amount of water which is not eliminated at a temperature of 212° F. Under the microscope it only exhibits well-defined fluid-cavities in specimens that are more than usually crystalline; and these, even in the same crystal, when heated, become full at by no means uniform temperatures.

(4) Mineral veins of evidently very recent date are met with in various localities on the Pacific coast; and some of these contain both gold and silver.

(5) In addition to the gold found in quartz veins, this metal occurs in certain bands of metamorphosed slates. The outcrops of these, like those of ordinary veins, are frequently coloured red or brown by the decomposition of pyrites.

(6) The old Tertiary river-beds constituting the deep diggings, and frequently overlain by a volcanic capping, contain large

quantities of fossil wood, and are often hardened into a compact conglomerate by a cement consisting either of finely crystallized iron pyrites or of silica. This iron pyrites encloses gold, which is sometimes water-worn, and at others is in a crystalline or filiform state, showing that it has not been subjected to attrition. In Australia, pyrites replacing the woody constituents of the stems of trees found in similar positions has been shown by various chemists to contain large quantities of the precious metal. The siliceous cement of the ancient river-beds of California has sometimes, but rarely, been deposited in a crystalline form, and on examination such crystals have not been found to contain fluid-cavities presenting the usual vacuities.

(7) Mineral springs are exceedingly numerous, and their waters generally escape from the ground in a state of ebullition. These springs deposit silica, sulphur, iron pyrites, &c., whilst in some instances cinnabar is brought to the surface in large quantities by solfatara action; occasionally the deposited silica takes the form of an ordinary auriferous vein, and gold is stated on good authority to have been found in quartz so produced. At the surface the silica of such deposits contains a larger amount of water than that of the older quartz veins of the country, but appears gradually to lose it, and, although generally amorphous, is sometimes met with in a crystallized state.

(8) In the districts abounding in mineral springs are lakes of which the waters are highly alkaline, and which, in addition to carbonates and sulphate of soda, contain large quantities of chloride of sodium. These have no visible outlets, and act as vast evaporating-pans, in which the waters of the various streams flowing into them are being concentrated by the action of the sun's rays. The incrustations deposited on the shores of Owen's Lake contain a much larger proportion of carbonate of soda than the salts obtained by direct evaporation of the lake-waters.

In the present state of our knowledge, the foregoing facts would appear to lead to the following conclusions:—

(*a*) Quartz veins have been produced by the slow deposition, from aqueous solutions, of silica on the surfaces of the enclosing fissures*.

(*b*) From the general parallelism with its walls of the planes of any fragments of the enclosing rock which may have become imbedded in a vein, it is to be inferred that they were mechanically removed by the growth of the several layers to

* By "aqueous solution" it is not intended to convey the idea that silica has been dissolved in pure water, but rather in waters containing various acids, alkalies, salts, &c.

which they adhered, and that a subsequent deposition of quartz took place between them and the rock from which they had become detached. In this way were introduced the masses of rock known as "horses."

(*c*) The formation of quartz veins is often due to hydrothermal agencies operating from below, of which evidences are still to be found in the hot springs and recent metalliferous veins to be met with in various parts of the Pacific coast.

(*d*) From the presence of gas-cavities and the variable temperatures at which the vacuities in their fluid-cavities become filled, it may be inferred that they are the result of an intermittent action, and that the fissures were sometimes traversed by currents of hot water, whilst at others they gave off aqueous vapour or gaseous exhalations*.

This is precisely what is now taking place at Steamboat Springs, where the formation of a vein is in progress, and from which currents of boiling water are often poured forth, whilst at other times the fissures only give off currents of steam and heated gases.

(*e*) That gold may be deposited from the same solutions which give rise to the formation of the enclosing quartz, would appear evident from the presence of that metal in pyrites enclosed in siliceous incrustations near Borax Lake, in the semi-opal of the North Star vein &c., as well as from the fact of gold having been found in the interior of the stems of trees which in deep diggings are often converted into pyrites.

(*f*) The constant presence of iron pyrites in auriferous veins, and when so occurring its invariably containing a certain amount of gold, suggests the probability of this sulphide being in some way necessarily connected with the solvent by which the precious metal was held in solution. Without considerable addition to our present limited knowledge of the subject, it would be impossible to explain the exact process by which the solution of gold was effected. It has, however, been shown by Wurtz† (who has since suggested the probability of ferruginous salts being the means employed by nature for effecting the solution of gold‡) that finely divided gold is soluble in the sesquichloride of iron, and more sparingly in the sesquisulphate of that metal. It is also well known that iron pyrites sometimes results from the action of reducing agents on the sulphates of iron.

* Sorby, "On the Microscopical Structure of Crystals. § 1. *Crystals formed from solution in water*," Quarterly Journal of the Geological Society, vol. xiv. pp. 453–500.

† American Journal of Science, vol. xxvi. p. 51.

‡ Memoir read before the American Association for the Advancement of Science, August 1, 1866.

If, therefore, sulphate of iron, in a solution containing gold, should become transformed by the action of a reducing agent into pyrites, the gold, at the same time being reduced to the metallic state, would probably be found enclosed in the resulting crystals of that mineral*.

(*g*) The silica and other substances forming the cementing material of the ancient auriferous river-beds have probably been slowly deposited from comparatively cold solutions.

(*h*) The connexion existing between the decomposition of felspar by the agency of boiling springs, the existence of alkaline plains, and the formation of lakes containing various salts of soda and potash will be at once obvious to the geologist.

* From a somewhat lengthy investigation of the subject, I am induced to believe that gold invariably occurs in pyrites and other sulphides in the metallic form. Tarry matter, like that found in the solfatara at Borax Lake, has occasionally been met with in the quartz veins of California; and although the protosulphate of iron, resulting from the decomposition of the sesquisulphate, would, under certain circumstances, have the effect of precipitating gold from solution, it would probably not do so in the presence of large quantities of the persalts of that metal. A discovery, made by Mr. Daintree, of the fact that a speck of gold lying in a solution of the chloride of that metal may be increased to several times its original weight by the action of a small piece of cork introduced into the solution, is recorded by Mr. Ulrich. Mr. Wilkinson's experiments further prove that, besides gold itself, iron, copper, and arsenical pyrites, galena, blende, &c. likewise form favourable nuclei, which, if immersed in weak solutions of chloride of gold, receive a solid coating of metal by the agency of organic matter, such as a chip of wood floating in the solution.—'Notes on the Physical Geography, Geology, and Mineralogy of Victoria' (*ante cit.*), p. 44.